Risk-based Decision-making Guidelines

Volume 3
Procedures for Assessing Risks

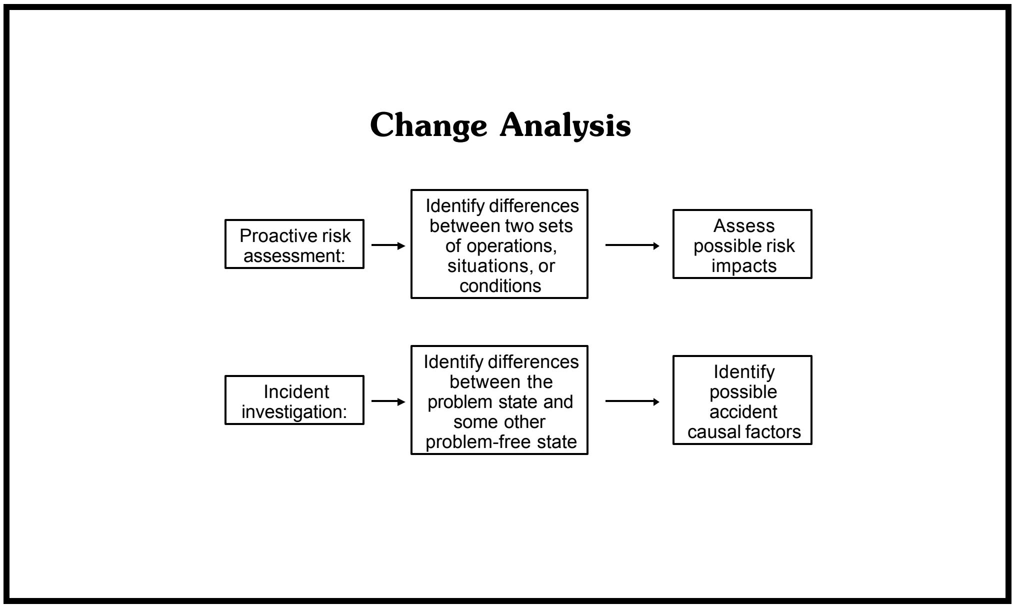
Applying Risk Assessment Tools

Chapter 7 — Change Analysis

Chapter Contents

This chapter provides a basic overview of the change analysis technique and includes fundamental step-by-step instructions for using this methodology to assess the potential for accidents in changing situations and environments. Following are the major topics in this chapter:

See examples of change analysis in Volume 4 in the Change Analysis directory under Tool-specific Resources.



Summary of Change Analysis

Change analysis looks systematically for possible risk impacts and appropriate risk management strategies in situations where change is occurring. This includes situations in which system configurations are altered, operating practices or policies are changed, new or different activities will be performed, etc.

Brief summary of characteristics

- Systematically explores all of the differences from normal operations and conditions that may introduce significant risks or may have contributed to an actual accident
- Is used effectively for proactive hazard and risk assessment in changing situations and environments as well as during accident investigations
- Can be used to identify changes in overall risk profiles, when used in conjunction with other methodologies such as the preliminary risk analysis methodology described in Chapter 6
- Is a conceptually simple tool that can be implemented in a reasonable amount of time

Most common uses

- Generally applicable to any situation in which change from normal configuration, operations, or activities is likely to significantly affect risks. An example would be marine events in ports or waterways
- Can be used as an effective root cause analysis method as well as a predictive risk assessment method

Example

Change Analysis of Raising the *HUNLEY*			
		Recommended Risk Control Strategies	
Differences from Normal Port Activities	**Potential Effects**	**Prevention Requirements**	**Surveillance Actions**
Conducting the lift, placing the *HUNLEY* on the transport barge, and connecting the tug for tow (Lifting Phase)			
Increased radio traffic, primarily due to high volume of recreational boaters	Communication delays affecting SAR response, zone protection, mission coordination, bridge openings and closings, attitudes of recreational boaters, other commercial traffic, pilot operations, etc.	Develop a coordinated port operations and emergency communications plan among the MSO, Group, EPD, SCDNR, CCPD, and the sheriff's department (including secondary and tertiary equipment capability, such as an 800 MHz system and cell phones, as backup) **[Responsibility: USCG MSO/Group]** Acquire the necessary equipment, such as the 800 MHz system, to implement the communication plan **[Responsibility: USCG MSO]** Train Coast Guard staffs to implement the communications plan **[Responsibility: USCG Group Ops]**	Plan a radio check upon initiation of the plan and a verification check on scene **[Responsibility: USCG]** Plan an equipment verification prior to the event, based on a checklist associated with the plan **[Responsibility: All enforcement agencies, facilitated by USCG Group Ops]**
Concentrated vessel traffic near the recovery zone	Increased likelihood of marine casualties and disorderly conduct among observers Potential for reduced visibility and mobility for USCG surveillance and response assets Increased likelihood of penetration of the safety zone, possibly affecting the *HUNLEY* recovery work and consuming Coast Guard resources and attention	Publish the safety zone in a federal regulation **[Responsibility: USCG MSO]** Publish a notice to mariners, broadcast a notice to mariners, broadcast port community information, and notify local media **[Responsibility: USCG MSO]** Use other agencies to distribute safety zone information through their advertising mechanisms **[Responsibility: USCG MSO]** Clearly identify the safety zone with physical boundaries **[Responsibility: Sponsor]** Include a map of the harbor in publications defining the safety zone for the event **[Responsibility: USCG MSO]**	Develop a surveillance plan to dedicate appropriate resources to monitor the safety zone **[Responsibility: USCG MSO/Group Ops]** Verify that sponsor demarcations are consistent with the Coast Guard's defined safety zone **[Responsibility: USCG Group Ops]** Develop rules of engagement (specific for this activity) for vessels entering the safety zone **[Responsibility: USCG Group Ops]**

Example using change analysis as a root cause analysis tool

Change Analysis*

Problem Situation (describe) Journeyman contract electrician received fatal electrical shock during switchgear cleaning and inspection of NB02 at 2030 hours, 10/14

Circle One (Actual/Test/Procedure/Standard/Ideal)

Problem-free Situation (describe) Cleaning and inspection of PA02 safety-related switchgear conducted without apparent incident the week before during the same outage

Potential Differences	Conditions Found in PROBLEM Situation	Conditions Found in PROBLEM-FREE Situation	DIFFERENCES Between the Two Situations	How Could the Difference AFFECT This Problem?
Personnel	Journeyman contract electrician	Journeyman electrician	—	—
Personnel experience	Contract and in-house electricians working this job	Same contract and in-house electricians working this job	—	—
Power sources to breaker	NB02 has three sources of power	PA02 has two sources of power	NB02 has one more power source	Extra power source not tagged — remained shut — source of voltage — unrecognized
Type of bus	NB02 safety-related bus	PA02 safety-related bus	More critical loads on NB02. NB02 designed to keep power at all times. PA02 expected to be deenergized	Keeping power to RHR required power source — shift supervisor desired extra source — so two sources of power remained during work — not one as electricians expected
Clearance walk down	Clearance not walked down by electricians performing job	Clearance walked down by electricians performing job	Verbal communications used to establish lineup in problem situation	Removed one level of physical verification. Places more reliance on verbal communications and the physical voltage checks of switchgear
Pre-job brief	Pre-job brief consists of panel #s and "same as last week"	Pre-job brief included panel #s, job, hold points, safety precautions, and detailed discussion of job	Less detail in problem situation briefing	Less detail in brief caused reliance on memory as to precautions. Job was not the same. Extra power sources, safety related vs. nonsafety related, caused additional concern
Use of "Hot" stickers	"Hot" stickers used on known energized cubicle in the panel	"Hot" stickers not used	Presence of "Hot" stickers	New, undocumented system of labeling known power sources may have bred false sense of security. "Hot" stickers not on second energized cubicle in panel
Schedule	Outage scheduled for 49 days with at least 54 days of electrical work	Outage scheduled for 49 days with at least 54 days of electrical work	—	—

*excerpted from the OSHA Training Institute

Limitations of Change Analysis

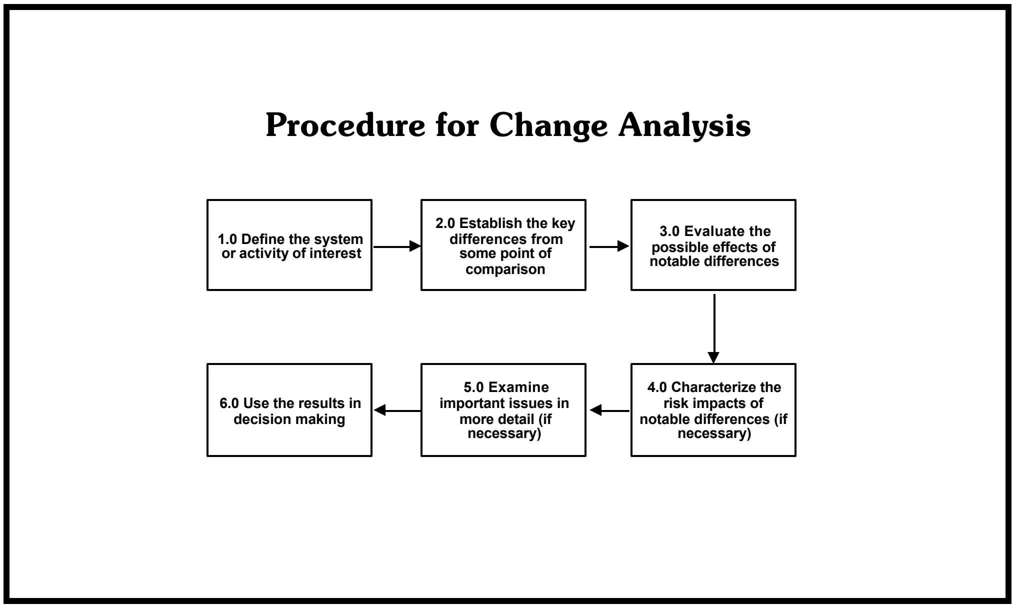
- **Highly dependent on points of comparison**
- **Does not inherently quantify risks**
- **Strongly dependent on the expertise of those participating in the analysis**

Limitations of Change Analysis

Highly dependent on points of comparison. Change analysis relies on comparisons of two systems or activities to identify weaknesses in one of the systems in relation to the other. Thus, an appropriate point of comparison is very important.

Does not inherently quantify risks. Change analysis does not traditionally involve quantification of risk levels; however, the results of change analysis can be used with other risk assessment methods that produce quantitative risk characterizations, such as the preliminary risk analysis method.

Strongly dependent on the expertise of those participating in the analysis. The knowledge and experience of the people participating in a change analysis strongly affect their ability to recognize and evaluate notable differences between the system or activity of interest and the point of comparison. In addition, the expertise and experience of the participants certainly affect the quality of the risk management options that are identified.



Procedure for Change Analysis

The procedure for performing a change analysis consists of the following six steps:

1.0 Define the system or activity of interest. Specify and clearly define the boundaries of any physical system or operational activity of interest.

2.0 Establish the key differences from some point of comparison. Choose a comparable physical system or operational activity that is well understood and would expose weaknesses in the system or activity of interest when comparisons are made. Then, systematically identify all of the differences, regardless of how subtle, between the system or activity of interest and the chosen point of comparison.

3.0 Evaluate the possible effects of notable differences. Examine each of the identified differences, and decide whether each has the potential to contribute to losses of interest. This evaluation often generates recommendations to better control any significant risks associated with notable differences.

4.0 Characterize the risk impacts of notable differences (if necessary). Use some type of risk characterization approach, such as the quantitative risk categorization method used with the preliminary risk analysis methodology, to indicate how the differences affect the risks of various types of losses. (This type of risk categorization is seldom necessary when change analysis is used during an accident investigation).

5.0 Examine important issues in more detail (if necessary). Analyze important potential accidents further with other risk analysis tools or other accident investigation tools.

6.0 Use the results in decision making. Use the results of the analysis to identify significant system or activity vulnerabilities and to make effective recommendations for managing the risks.

1.0 Define the system or activity of interest

- **Proactive risk assessments**
  - **marine events**
  - **new vessels or operations in a port or waterway**
  - **changes in prevention, monitoring, and other surveillance activities for a port or waterway**
  - **changes in port or waterway management and configuration**
- **Accident investigations (any type of loss)**

1.0 Define the system or activity of interest

Specify and clearly define the boundaries of any physical system or operational activity of interest. A clear understanding of the system or activity is critical to identifying its vulnerabilities.

Proactive risk assessments. Change analysis is very effective for identifying areas of risk that may develop if proposed changes in equipment configuration, operational conditions, or environmental situations occur. Some typical applications of change analysis include the following:

- Marine events that temporarily affect activities in and around a port or waterway. These include parades, races, fireworks displays, etc.
- A request to allow larger cargo tankers to transit through a waterway or into a port
- A change in crew size for a type of vessel
- Physical changes in ports or waterways. These include moving traffic lanes, relocating anchorages, changing loading or unloading facilities, etc.
- A proposed or actual change in regulatory requirements

Example

The following table defines the range of activities associated with a major marine event in a port, which invariably introduces unique risks into the port.

Separate Marine Events Likely to be Associated with OPSAIL 2000 in a Port

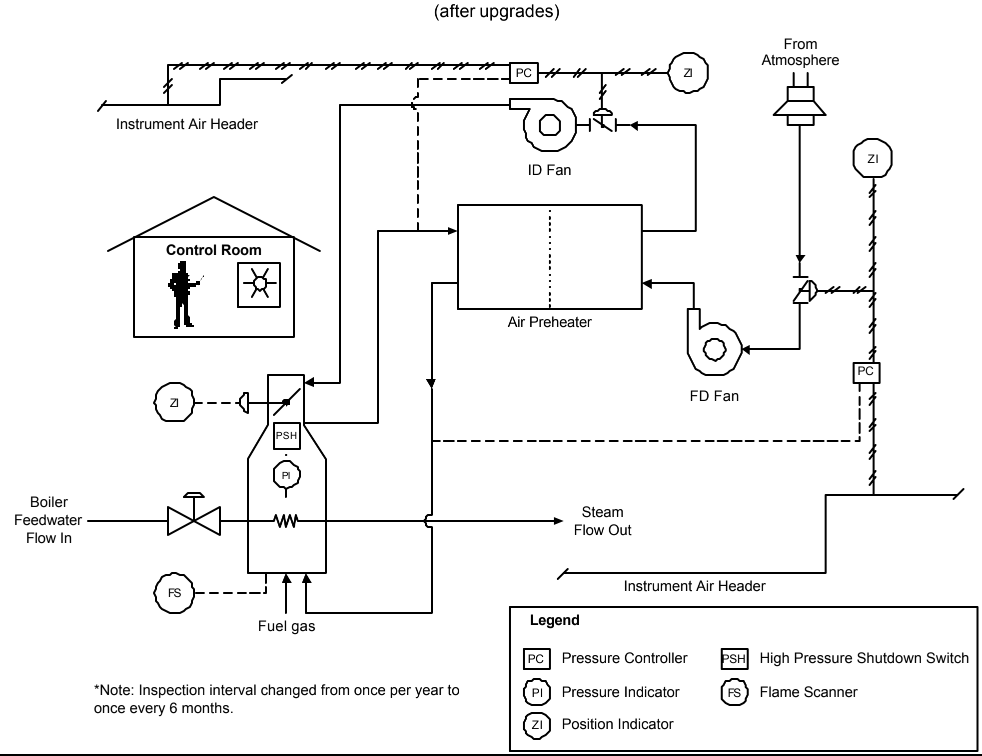
Mass arrival of tall ships and their entourage
Arrival and departure of individual ships associated with the event
Vessel parades during port stay
Shoreside festivities during stay of tall ships and their entourage (each treated as a separate marine event) • Tours of vessels • Fireworks • Races of smaller vessels • Etc.
Mass departure of tall ships

Accident investigations. Change analysis is also very effective during investigations of virtually any type of loss.

Example

The shore facility boiler system shown below has started experiencing inadvertent shutdowns that affect facility operations and can lead to safety events. These events are being investigated to prevent future reliability and safety problems.

#4 Steam Boiler
(after upgrades)



2.0 Establish the key differences from some point of comparison

- **For proactive risk assessments, compare to routine, normal operations**
- **For accident investigations, compare to previous successful operations, regulatory or standard basis, and idealized models**

2.0 Establish the key differences from some point of comparison

Choose a comparable physical system or operational activity that is well understood and would expose weaknesses in the system or activity of interest when comparisons are made.

Proactive risk assessments. A change analysis performed during a proactive risk assessment is typically a comparison between some altered system or activity and routine, normal operations associated with the system or activity. Thus, the point of comparison is generally the routine, normal operating situation.

Accident investigations. A change analysis performed during an accident investigation is typically a comparison between some problem state, such as an accident or other equipment casualty, and some comparable problem-free state for a system or activity. The problem-free state that serves as the point of comparison strongly influences the capability of the analysis to uncover important differences that may have contributed to the accident. Some of the most common points of comparison during accident investigations include the following:

- **Previous successful operation.** Comparisons can be made to successful operations or activities yesterday, last week, last month, last year, etc. Also, comparisons can be made to other operations or activities of the same type that are currently being performed with no difficulties.
- **Regulatory or standard basis.** Comparisons can be made to requirements established in applicable regulations or industry standards.

- **Idealized models.** Comparisons can be made to theoretically *perfect* conditions, such as the design model explaining how the system or activity was supposed to work.

Once the point of comparison is established, then systematically identify all of the differences, regardless of how subtle, between the system or activity of interest and the chosen point of comparison. At this point, the goal is simply to recognize the differences, not to judge them. The differences may take many forms, including the following:

- Technological or equipment changes
- Personnel changes
- Procedural changes
- Organizational changes
- Environmental changes
- Schedule changes
- Material supply changes

The following table provides some useful guide words that help identify differences that may exist.

Examples of types of changes that can cause losses*

Substitute	**Rearrange**	**Reduce**	**Modify**
Power	Sequence	Omit	Color
Ingredients	Pace	Shorten	Shape
Process	Components	Split	Sound
Approach	Schedule	Condense	Odor
	Pattern		Motion
			Meaning
Combine	**Adopt**	**Reverse**	Light
Blend	Outright	Order	
Units	Related	Direction	
Assortment			
Ensembles			

*excerpted from Ferry's *Modern Incident Investigation.*

Example for a proactive risk assessment

The point of comparison for a temporary marine event in a port is typically normal, routine port operations. The following table identifies the notable differences between a hypothetical marine event and normal port operations.

Key Differences Between Normal Port Activities and the Mass Arrival of Tall Ships and Their Entourage

1.	Arrival of tall ships and their entourage in the port • Transit up river beginning at approximately 7:00 a.m. on a Saturday in June • Vessel parade from approximately 9:00 a.m. to approximately 6:00 p.m. through port • Moor at inner harbor, at piers along the river, and at anchorage sites along the river from approximately 6:00 p.m. to approximately 9:00 p.m.
2.	Large increase in tug traffic, assisting tall ships and their entourage
3.	Large increase in recreational vessel traffic (all types of vessels and crew skills expected) • On river • At inner harbor • Entering and exiting marinas and commercial establishments
4.	Large increase in passenger vessel traffic • Tours • Taxis • VIP launches
5.	Increase in official vessel traffic • Coast Guard vessels • Port police • Firefighting and other emergency response vessels
6.	Increase in aviation activities over the river and port • Television helicopters • Security surveillance • Emergency response helicopters • Civilian aircraft
7.	Masses of people along the shore • Accessible locations up river of the key bridge • Throughout the harbor
8.	Traffic congestion in areas around the port (roadways entering and leaving primary event sites)
9.	More fueling operations throughout the port (at marinas and through barge transfers)
10.	Presence of temporary floating piers (uncharted and difficult to see at night) around the port
11.	Major event with high-profile visitors and international participation, publicity, and media coverage

Example for an accident investigation

For the boiler system that began experiencing problems after a boiler upgrade project, the point of comparison for the problem state could be problem-free operations before the upgrade project. Following are the identifiable differences in boiler system configuration and operation introduced through the upgrade project:

- Audible alarms relocated from a local control panel to a central control room
- ID fan louver controller replaced with a different type of controller
- Instrument air supply line for the ID fan louver controller relocated
- Louver position indicators added
- Damper position indicator added
- Burners upgraded
- High pressure switch with boiler shutdown added for high firebox pressure
- Flame scanner with boiler shutdown added for loss of flame
- Boiler inspection interval increased from once every year to once every six months

These changes should then be evaluated to determine whether they could have been causal factors of the accident. This is explained in the next section.

3.0 Evaluate the possible effects of notable differences

- **For proactive risk assessment:**
  "How can this difference contribute to a an accident of interest?"
- **For accident investigation:**
  "Did this difference contribute to the accident being investigated?"

3.0 Evaluate the possible effects of notable differences

Examine each of the identified differences, and decide whether each has the potential to contribute to accidents of interest. This evaluation often generates recommended actions to better control any significant risks associated with notable differences.

Example for a proactive risk assessment

The following table details the analysis of one difference from normal port operations associated with a marine event. Similar analysis occurs for each difference.

Change Analysis of Mass Arrival of Tall Ships and Their Entourage			
Differences from Normal Port Activities	**Potential Effects on Port Activities**	**Recommended Risk Control Strategies**	
		Prevention Requirements	**Surveillance Actions**
1. Arrival of tall ships and their entourage in the port	Commercial traffic flow affected Sufficient number of local pilots may not be available Potential for insufficient anchorage space Some impacts on commercial fishing More congestion in waterway among event vessels Potential for insufficient pier space Potential for insufficient or incompatible shore facility support for event vessels Increased traffic on the radios	Work closely with the media to publicize event schedule (particular times/areas where waterway traffic may be impacted) Establish a liaison officer with commercial industry to plan schedules for minimizing commercial impact Establish specific radio frequencies to be used by different groups (a communications operations plan) Establish fixed zone along parade route (navigation channel and entire inner harbor area), possibly wider than channel (e.g., 200 ft), along channel Broadcast notice to mariners Require sponsor to place special markers along route (working with Coast Guard liaison to event)	Provide temporary vessel traffic management to coordinate commercial and event traffic Establish command posts with event sponsor to coordinate surveillance activities with event activities Provide for additional Coast Guard support of auxiliary vessels More small spill prevention patrols

Example for an accident investigation

The table on the following page details the analysis of differences for the boiler system before and after the upgrade project.

Change Analysis Form

Problem Title/Description: #4 Steam Boiler Shutdown **Date:** 1/8/97 **Problem Number:** RI-101

Problem Situation (describe): #4 Boiler had shut down due to new ID fan louver closing inadvertently

Problem-free Situation (describe): #4 Boiler had experienced reliability problems before shutdown, but reliability problem was worse after shutdown rather than better

Circle One: Actual/Test/Procedure/Ideal/Experience/Future

Conditions Found in Problem Situation	Conditions Found in Problem-free Situation	Differences Between the Two Situations	Resulting Effects
Biannual visual inspection	Annual visual inspection	More frequent inspection (none conducted yet)	—
Audible alarms located in the control room	Audible alarms located on a local control panel (unstaffed)	Location of alarms	Increased awareness of problems that probably went unnoticed in the past
ID louver controller upgraded	Originally installed ID fan louver controller in service	Design specs of new controller changed	Project engineer used lowest cost controller available; however, this type of controller had a documented history of problems at this site
Instrument air takeoff to ID fan louver controls relocated	Instrument air takeoff to ID fan louver controls located at an original point	New takeoff point is at a low point in the instrument air header	New instrument air source is located at a low point, which allowed settled debris in the line to affect the operation of the controller, the louver position indicator, or the valve
Louver position indicators available	Louver position indicators are unavailable	Presence of louver position indicators	Operators relied exclusively on the louver position indicator instead of other physical observations about louver position (e.g., the mechanical linkage position)
Damper position indicator is available	Damper position indicator is unavailable	Presence of damper position indicator	—
Burners upgraded	Originally installed burners	Design specs on new burners changed	—
Boiler shutdown on high firebox pressure available	Boiler shutdown on high firebox pressure unavailable	Presence of a boiler shutdown on high firebox pressure	Shutdown occurred during an event that might not have been noticed previously
Flame scanners available	Flame scanners unavailable	Presence of flame scanners	—

4.0 Characterize the risk impacts of notable differences (if necessary)

- **For proactive risk assessment:** **"How do the notable differences affect the frequencies or effects of various types of accidents?"**
- **Seldom necessary for accident investigations**

4.0 Characterize the risk impacts of notable differences (if necessary)

If necesary, a risk characterization approach may be used to reflect the differences associated with the risks of various types of accidents. One approach would be the risk categorization method used with the preliminary risk analysis methodology in Chapter 6. This type of risk categorization is seldom necessary when change analysis is used during an accident investigation. These risk characterizations can be used to generate an overall risk profile for the subject system or activity of interest when compared to normal operations.

Example for a proactive risk assessment

The table on the following page illustrates how notable differences in port operations introduced by a marine event affect the risks of some types of accidents. To develop the risk profile represented by this table, two tables defining frequency scores and loss severity categories are necessary. These two tables follow the risk profile table on the next page. More guidance for determining the risk index number (RIN) is on page 6-18 in the preliminary risk analysis (PrRA) procedure of Chapter 6 in this volume. The RINs in this example are divided by 365 to obtain the RIN for a single day of exposure versus the entire year. Other types of accidents are also affected by many of the same differences, but this excerpt does not address other accidents.

Item	Related Accidents from the Port-wide Risk Assessment	Differences from Normal Port Activities	Event-related Risk Estimates				
			Event-related Frequency Scores			Risk Index Number for Event	Score Certainty
			Major (1)	Moderate (2)	Minor (3)		
1	**Recreational** *Organized - Permitted Marine Event* Capsizing	1. Arrival of tall ships and their entourage in the port 3. Large increase in recreational vessel traffic	5	6	8	0.542	M
2	**Recreational** *Organized - Permitted Marine Event* Collision with another vessel	1. Arrival of tall ships and their entourage in the port 2. Large increase in tug traffic, assisting tall ships and their entourage 3. Large increase in recreational vessel traffic 4. Large increase in passenger vessel traffic 5. Increase in official vessel traffic	5	6	8	0.542	H
3	**Recreational** *Organized - Permitted Marine Event* Collision with a fixed object	1. Arrival of tall ships and their entourage in the port 3. Large increase in recreational vessel traffic	6	7	8	5.02	H
4	**Recreational** *Organized - Permitted Marine Event* Collision with a floating object	1. Arrival of tall ships and their entourage in the port 3. Large increase in recreational vessel traffic 10. Presence of temporary floating piers	4	5	8	0.095	M
5	**Recreational** *Organized - Permitted Marine Event* Grounding	1. Arrival of tall ships and their entourage in the port 3. Large increase in recreational vessel traffic	3	5	8	0.054	H
6	***Recreational*** *Organized - Permitted Marine Event* Sinking	1. Arrival of tall ships and their entourage in the port 3. Large increase in recreational vessel traffic	3	5	8	0.054	M

Frequency Scoring Categories

Frequency Score Descriptions	Frequency Scores (with frequency bounds)	Example Benchmarks (in days)
Continuous	8	
	100/y	1 in 4
Very Frequent	7	
	10/y	1 in 40
Frequent	6	
	1/y	1 in 400
Occasional	5	
	0.1/y	1 in 4,000
Probable	4	
	1×10^{-2}/y	1 in 40,000
Improbable	3	
	1×10^{-3}/y	1 in 400,000
Rare	2	
	1×10^{-4}/y	1 in 4,000,000
Remote	1	
	1×10^{-5}/y	1 in 40,000,000
Incredible	0	

Example Types of Effects*				
Severity	**Safety Impact**	**Environmental Impact**	**Economic Impact**	**Mission Impact**
Major (1)	One or more deaths or permanent disability	Releases that result in long-term disruption of the ecosystem or long-term exposure to chronic health risks	≥ $3M	≥ $3M
Moderate (2)	Injury that requires hospitalization or lost work days	Releases that result in short-term disruption of the ecosystem	≥$10K and <$3M	≥$10K and <$3M
Minor (3)	Injury that requires first aid	Pollution with minimal acute environmental or public health impact	≥ $100 and <$10K	≥ $100 and <$10K

* Losses in these categories result from both immediate and long-term effects (e.g., considering both acute and chronic effects when evaluating safety and health).

A representative equivalent loss for a major loss is $3,000,000, a moderate loss is $30,000, and a minor loss is $300.

The tables below and on the following pages show various ways to display the risk profile generated in this step. The first method is a simple table itemizing the potential accidents accounting for the highest risk for the event. The percentage of cumulative risk is determined by taking the ratio of the risk index number (RIN) for each accident and dividing it by the sum of all of the RINs for all potential accidents.

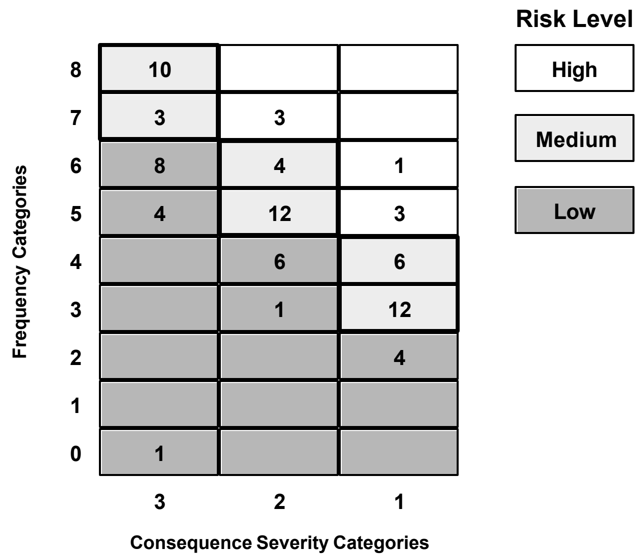
The second table describes the risk profile for the event in the form of a risk matrix. The risk matrix shows a distribution of the number of expected accidents across each severity category for each frequency score. The shaded areas reflect a predefined risk acceptance criteria showing which losses have High, Medium, or Low risk. Based on this risk matrix, priorities can be assigned to reduce the risk of potential accidents in the High and Medium categories.

The next two tables show how specific categories contributed to the risk. Categories include types of activities and types of accidents expected. The final table shows a summary of the expected number of accidents and expected equivalent loss associated with the marine event based on the risk profile.

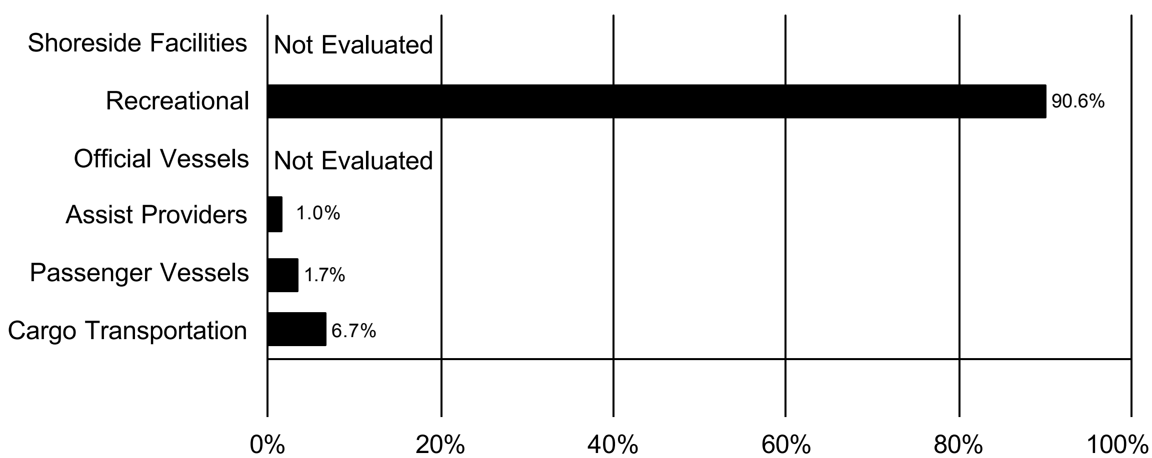
Highest Risk Losses

Potential Accidents	Event-related Risk Index Number	Percentage of Cumulative Risk for the Event
Recreational *Organized - Permitted Marine Event* Collision with a fixed object	5.02	60.7%
Recreational *Organized - Permitted Marine Event* Acute hazard exposure: passenger/crew	0.949	11.5%
Recreational *Organized - Permitted Marine Event* Capsizing	0.542	6.6%
Recreational *Organized - Permitted Marine Event* Collision with another vessel	0.542	6.6%
Recreational *Organized - Permitted Marine Event* Collision with a fixed object	0.542	6.6%
Recreational *Organized - Permitted Marine Event* Fire/explosion	0.136	1.6%
Recreational *Organized - Permitted Marine Event* Collision with a floating object	0.095	1.1%
Recreational *Organized - Permitted Marine Event* Environmental impact	0.091	1.1%
Others	0.35	4.2%
Total	8.267	100%

Marine Event Risk Matrix

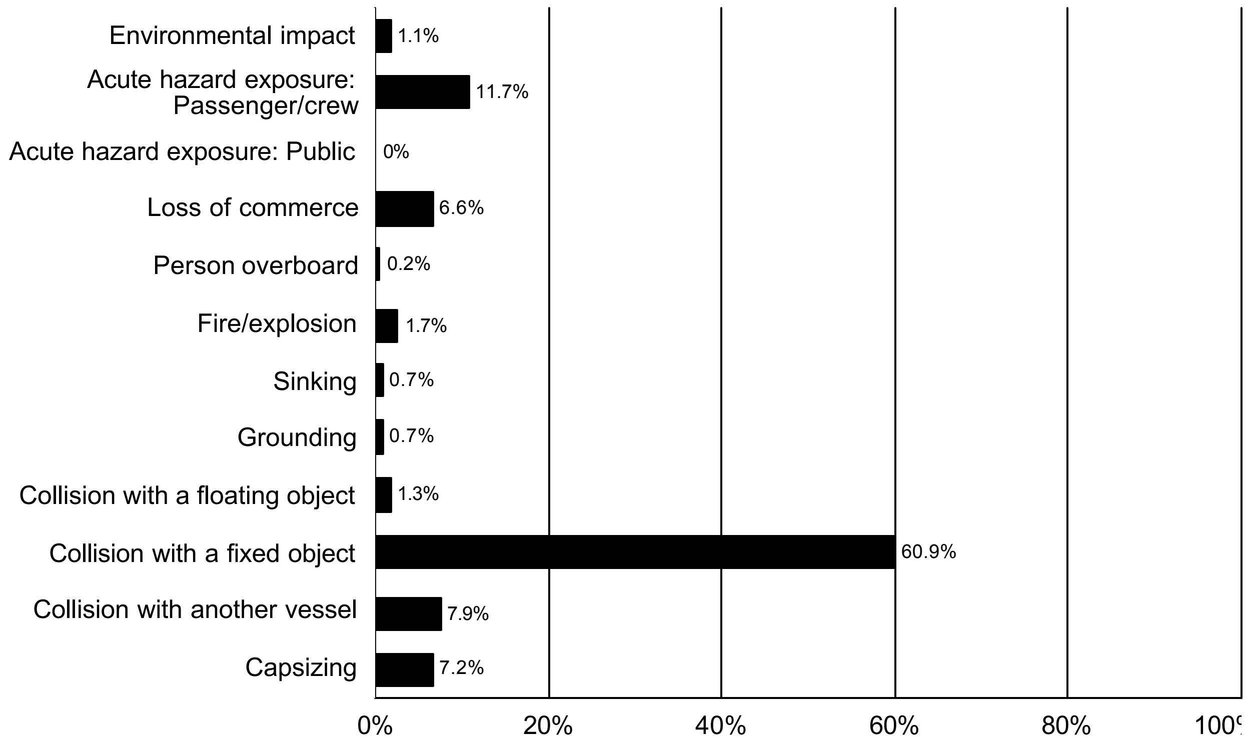


Marine Event Risk Profiles



Risk Contributions for the Marine Event Listed by Major Port Activities

Marine Event Risk Profiles (cont.)



Risk Contributions for the Marine Event Listed by Types of Losses

Loss Estimates for the Marine Event

	Major Losses	Moderate Losses	Minor Losses	All Losses
Expected Number of Accidents[1]	0.4% to 4% chance of occurrence	10% to 97% chance of occurrence	3 to 10	3 to 11
Expected Loss Exposure[2]	$11,000 to $113,000	$3,000 to $30,000	$1,000 to $3,000	$15,000 to $146,000

[1]Based on the assumption that the upper boundary for frequency category 8 would be 300 times per year.
[2]Based on the assumption that the average cost of losses is as follows: Major (1) - $3,000,000; Moderate (2) - $30,000; Minor (3) - $300

5.0 Examine important issues in more detail (if necessary)

- **For proactive risk assessments, use other assessment methods such as what-if or checklist analysis to focus on specific possible accidents and risk management options**
- **For accident investigations, investigate the underlying root causes of accident contributors using a tool like the Root Cause Map**

5.0 Examine important issues in more detail (if necessary)

Further risk assessment may be necessary for some notable issues revealed in the change analysis.

Proactive risk assessments. High-risk potential accidents may need to be explored further to develop the most effective prevention and response measures for managing the risks. In particular, a what-if or checklist analysis can be an effective method for understanding how the accidents might occur and what should be done to prevent or respond to them.

Accident investigations. Key contributors to accidents identified through the change analysis should be further investigated to find the underlying root causes of the problems. In particular, the Root Cause Map tool complements change analysis during accident investigations. The Root Cause Map is a type of checklist analysis technique presented in Chapter 4.

6.0 Use the results in decision making

- **Judge acceptability**
- **Make recommendations for improvements**
- **Justify allocation of resources for improvements**

6.0 Use the results in decision making

Use the results of the risk assessment to identify significant system or activity vulnerabilities and to make effective recommendations for managing the risks.

Judge acceptability. Decide whether the risk of potential accidents, or repeated accidents in the case of accident investigations, is tolerable.

Make recommendations for improvements. Use the suggestions developed through the change analysis to compile a list of recommendations for preventing or responding to potential accidents.

Justify allocation of resources for improvements. Estimate how implementation of expensive or controversial recommendations for improvement will affect risks. Compare the benefits of these improvements to the total life-cycle costs of implementing each recommendation.